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ABSTRACT

This document presents a secondary level physics unit which introduces students to the Wheatstone Bridge, its use in determining the value of unknown resistors, and the effects of wiring resistors in series or in parallel. (SL)

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USING THE WHEATSTONE BRIDGE TO COMPUTE UNKNOWN RESISTANCES

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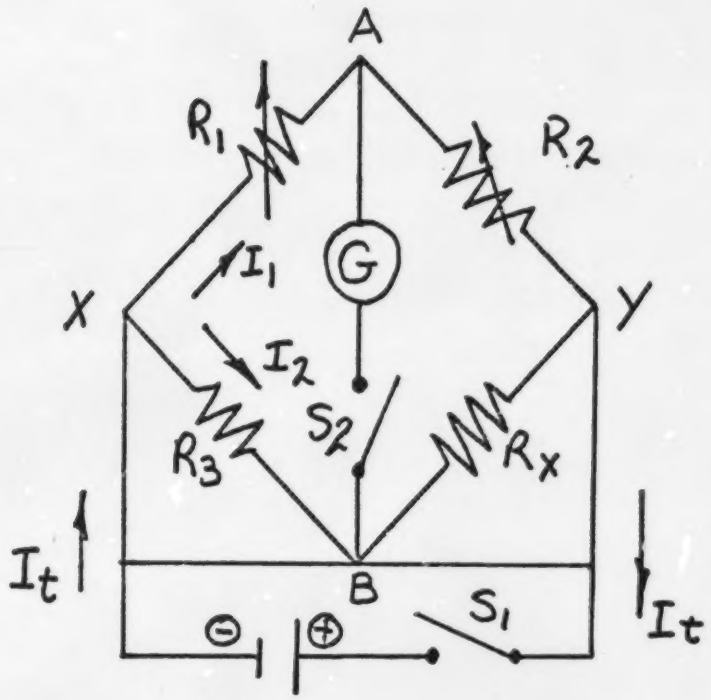
ABSTRACT

Students are introduced to the general theory behind the operation of the Wheatstone Bridge. The general introduction is followed by a more specific introduction to a slide wire Wheatstone Bridge. Students then use the bridge to determine the values of single unknown resistors, resistors wired in series and resistors wired in parallel.

INTRODUCTION

The Wheatstone Bridge is a device which you will use to ascertain the values of unknown resistors. A schematic diagram of the instrument is shown in Figure 1.

Figure 1. A Schematic Diagram of the Wheatstone Bridge Circuit.

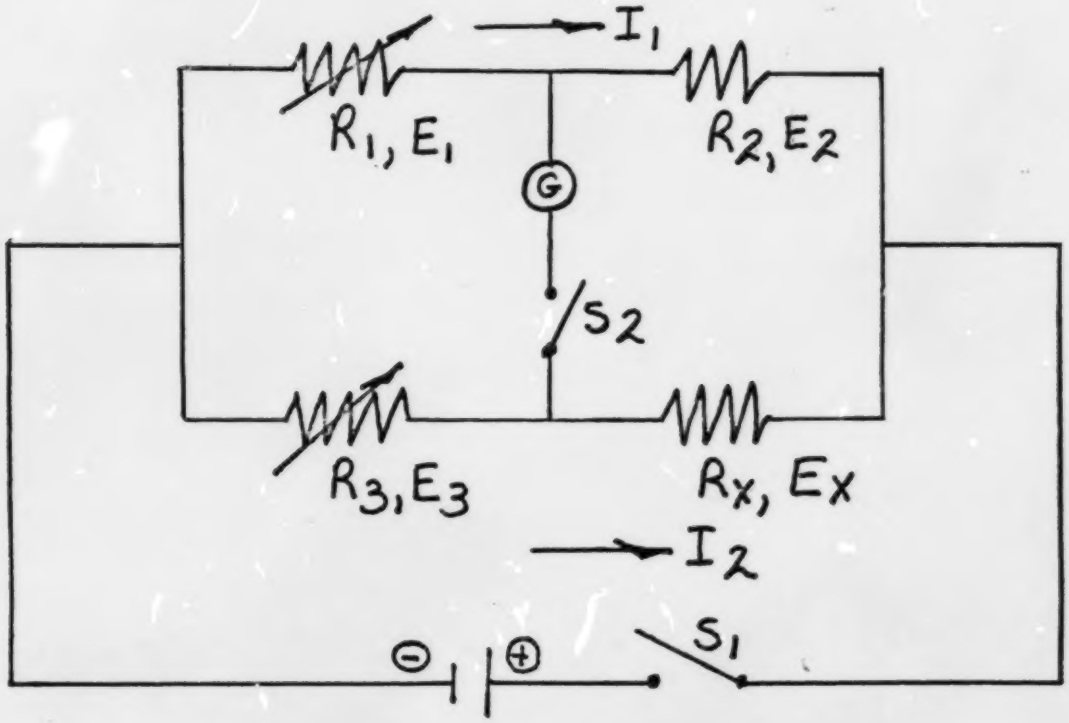


Resistors R_1, R_2, and R_3 are precision variable resistors while R_x is the resistor whose value is unknown. The galvanometer, labeled G, is used to indicate when there is a balance between points A and B, that is, when the bridge is balanced, a zero reading on the galvanometer indicates that there is no difference in potential between points A and B.

The bridge operates as follows: Current flows from the negative

side of the battery to point X where it divides into currents I_1 and I_2 (Current divides in a parallel circuit). The currents then unite again at point Y to form I_t. The magnitude of current I_1 depends upon the values of R_1 and R_2, and I_2 depends upon the values of R_3 and R_x (remember that x is equivalent to unknown). Resistors R_1, R_2, and R_3 are adjusted such that when switch S_2 is closed, the galvanometer will read zero or no deflection. Again, no deflection or zero deflection means that there is no difference in potential between points A and B. This means that the voltage drop, E_1 across R_1 is equivalent to the voltage drop E_3 across R_3, see Figure 2.

Figure 2. Modified Bridge Circuit Schematic.



By similar reasoning, the voltage drops across R_2 (E_2) and R_x (E_x) are also equal. Since

$$E_1 = E_3 \text{ and } E = IR,\ I_1R_1 = I_2R_3 \text{ and}$$

$$E_2 = E_x,\ I_1R_1 = I_2R_x$$

Therefore,

$$\frac{I_1R_1}{I_1R_2} = \frac{I_2R_2}{I_2R_x} \text{ and } \frac{R_1}{R_2} = \frac{R_3}{R_x} \text{ Thus, } R_x = \frac{R_2R_3}{R_1}$$

OBJECTIVES

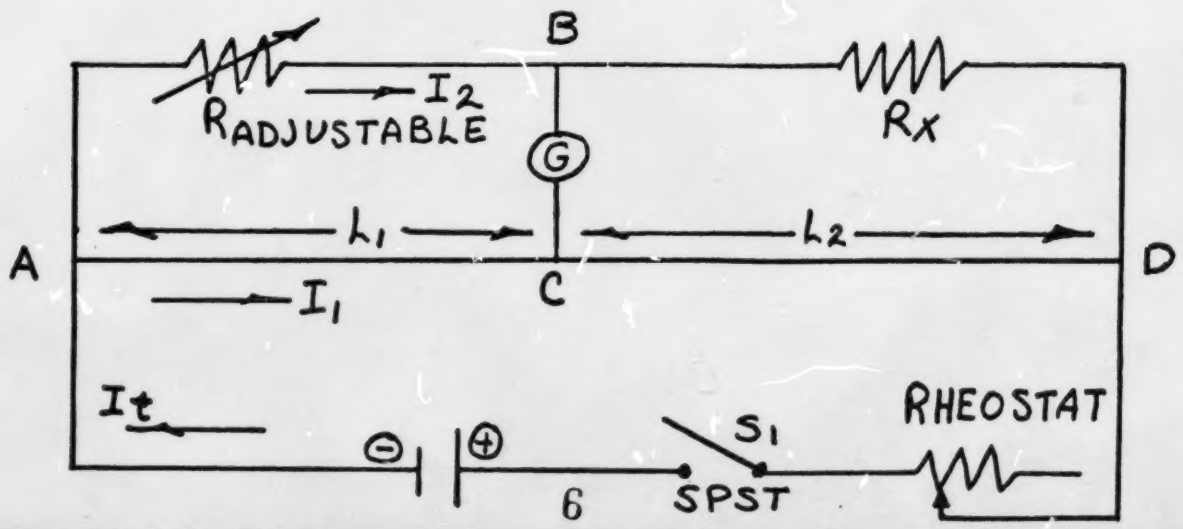
As a result of participation in this laboratory exercise, the student will be able to:

1. Use a Wheatstone Bridge to measure resistance.
2. Compute the values of unknown resistances from the data collected with a Wheatstone Bridge.
3. Describe the operation of the Wheatstone Bridge.

DISCUSSION

The Wheatstone Bridge used in this exercise is of the sliding wire type. A modified circuit design of this Bridge is shown in Figure 3.

Figure 3. A Modified Schematic Diagram of the Wheatstone Bridge.



The variable resistor which is marked RHEOSTAT is wire wound. It is set in about the center of its resistance range (the range is small). The function of this resistance is to limit current flow when R_x is not present; that is, to limit current flow in the event that S_1 is inadvertantly closed when the Bridge is not being used to measure a resistance.

Notice that there is a finger depressable switch located at point B. When this is not depressed, point B can be moved along the wire. Thus, distances L_1 and L_2 may be changed. Since wire AD is a resistive wire, lengths L_1 (AC) and L_2 (DC) function as resistances in parallel with $R_{ADJUSTABLE}$ AND R_x. Changing the location of $R_{ADJUSTABLE}$ position C effectively then changes the resistance of L_1 and L_2. Wire AD is one meter long. For preliminary investigations L_1 should equal L_2 (L_1 = 50cm and L_2 = 50cm).

The galvanometer reads the difference in potential between points B and C. When the galvanometer reads zero, there is no difference in potential between B and C and the voltage at C (E_C) is equal to the voltage at B (E_B) ($F_C = E_B$). In this situation, the voltage drops between AB and AC are equal.

$E_{AB} = E_{AC}$ and since $E = IR$ $I_2R_{AB} = I_1R_{AC}$

In addition, since $L_1 = L_2$, and $R_{AC} = R_{DC}$, $R_{ADJUSTABLE} = R_X$. Also, since current in a series circuit is common, I_1 flows through L_1 and L_2 and I_2 flows through $R_{ADJUSTABLE}$ and R_X. From this it follows that the voltage drop across R_X equals the voltage drop across CD.

$$E_{BD} = E_{CD} \quad \text{and} \quad I_1R_{CD} = I_2R_{BD}$$

Since R_{CD} is determined by the length of L_2, $R_{L_2} = R_x$ by dividing

$$\frac{I_2 R_{ADJUSTABLE} = I_1 L_1}{I_2 R_x = I_2 L_2} \qquad R_x = R_{ADJUSTABLE} \frac{L_2}{L_1}$$

Resistor, $R_{ADJUSTABLE}$, is used to adjust the voltage drop across AB. When this resistor is properly adjusted, the galvanometer will read zero.

This bridge may be used to ascertain the values of single resistors, resistors in resistors, and resistors in parallel.

MATERIALS

1. One 1.5 volt battery.
2. One Wheatstone Bridge.
3. A resistor board which has at least three unknown resistors mounted on it.
4. Several lengths of hookup wire.

PROCEDURES

1. Determine singly, the resistance of each of three unknown resistors.
2. Determine the total resistance of the three unknown resistors wired in a series configuration.
3. Determine the total resistance of the three unknown resistors wired in parallel.

REFERENCES

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2. Smith, A.W., and Cooper, J.N., Elements of Physics, Eighth Edition. McGraw Hill Book Company: New York, 1972.